USE OF WASTE POLYETHYLENE IN BITUMINOUS CONCRETE MIXES

A Thesis submitted in partial fulfillment of the requirements for the degree of Bachelor of Technology in "Civil Engineering"

By

BISWANATH PRUSTY (108CE036)

Under the guidance of

Prof. MAHABIR PANDA

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CERTIFICATE

This is to certify that the thesis entitled "**Use of waste polyethylene in bituminous concrete mixes**" submitted by Biswanath Prusty to the National Institute of Technology, Rourkela, in partial fulfilment of the requirements for the award of Bachelor of Technology in Civil Engineering, at the National Institute of Technology, Rourkela is an authentic research work carried out by him under my supervision and guidance.

To the best of my knowledge, the results embodied in this thesis have not been submitted to any other University or Institute for the award of any degree or diploma.

Date: 14^{th} May, 2012

Place: NIT Rourkela

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Biswanath Prusty

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ABSTRACT

Bituminous Concrete (BC) is a composite material mostly used in construction projects like road surfacing, airports, parking lots etc. It consists of asphalt or bitumen (used as a binder) and mineral aggregate which are mixed together & laid down in layers then compacted.

Now a days, the steady increment in high traffic intensity in terms of commercial vehicles, and the significant variation in daily and seasonal temperature put us in a demanding situation to think of some alternatives for the improvisation of the pavement characteristics and quality by applying some necessary modifications which shall satisfy both the strength as well as economical aspects.

Also considering the environmental approach, due to excessive use of polythenes in day to day business, the pollution to the environment is enormous. Since the polythenes are not biodegradable, the need of the current hour is to use the waste polythene in some beneficial purposes.

This paper presents a research conducted to study the behavior of BC mix modified with waste polythene.

Various percentages of polythene are used for preparation of mixes with a selected aggregate grading as given in the IRC Code. The role of polythene in the mix is studied for various engineering properties by preparing Marshall samples of BC mixtures with and without polymer. Marshall properties such as stability, flow value, unit weight, air voids are used to determine optimum polythene content for the given grade of bitumen (80/100).

Key words : Bituminous Concrete (BC), Marshall stability, Flow value, Optimum Polythene Content

CHAPTER 1

INTRODUCTION

INTRODUCTION

1.1 General

Bituminous binders are widely used by paving industry. A pavement has different layers. The main constituents of bituminous concrete (BC) are aggregate and bitumen. Generally, all the hard surfaced pavement types are categorized into 2 groups, i.e. flexible and rigid.

i. Flexible Pavement :

If the surface course of a pavement is bitumen then it is called "flexible" since the total pavement structure can bend or deflect due to traffic loads.

ii. Rigid Pavement :

If the surface course of a pavement is PCC then it is called "rigid" since the total pavement structure can't bend or deflect due to traffic loads. Such pavements are much stiffer than the flexible pavements due to the high modulus of elasticity of the Plain Cement Concrete material. Importantly, we can use reinforcing steel in the rigid pavements, to decrease or eliminate the joints.

1.2 Mix Design

1.2.1 Overview

Construction of highway involves a huge outlay of investment. An accurate engineering design can save considerable investment; as well, a reliable performance of the highway, can be achieved.

1.2.2 Objectives of mix design

The bituminous mix design aims to estimate the proportions of bitumen, filler material, fine aggregates, coarse aggregates & polythene to produce a mix which should have

- Sufficient workability so that there is no segregation under load

- Enough strength to survive heavy wheel loads & tyre pressures.
- Sufficient durability
- Should be economical

1.2.3 Types of mix

- Hot mix asphalt concrete
- Warm mix asphalt concrete
- Cold mix asphalt concrete
- Cut-back asphalt concrete
- Mastic asphalt concrete or sheet asphalt

1.3 Polymer modification of BC

1.3.1 Need of the hour

The steady increase of wheel loads, tyre pressure, change in climatic conditions & daily wear and tear severely affect the performance of bituminous mix pavements. Hence any improvement in the property of the pavement is highly essential considering the present scenario.

1.3.2 Waste plastic is a concern

Plastics are durable & non-biodegradable; the chemical bonds make plastic very durable & resistant to normal natural processes of degradation. Since 1950s, around 1 billion tons of plastic have been discarded, and they may persist for hundreds or even, thousands of years. The plastic gets mixed with water, doesn't disintegrate, and takes the form of small pallets which causes the death of fishes and many other aquatic animals who mistake them as food materials.

Today the availability of the plastic wastes is enormous, as the plastic materials have become the part and parcel, of our daily life. Either they get mixed with the Municipal Solid Waste or thrown over a land area. If they are not recycled, their present disposal may be by land filling or it may be by incineration. Both the processes have significant impacts on the environment. If they are incinerated, they pollute the air and if they are dumped into some place, they cause soil & water pollution. Under these circumstances, an alternate use for these plastic wastes is required.

1.3.3 Role of plastic or polymer in pavement

Modification of BC, with the synthetic polymer binder can be considered as a solution to overcome the problems, arising because of the rapid increase in wheel loads and change in climatic conditions. Polymer modification can be considered as one of the solution to improvise the fatigue life, reduce the rutting & thermal cracking in the pavement.

Asphalt, when blended or mixed with the polymer, forms a multiphase system, containing abundant asphaltenes which are not absorbed by the polymer. This increases the viscosity of the mix by the formation of a more internal complex structure.

CHAPTER 2

LITERATURE REVIEW

REVIEW OF LITERATURE

2.1 Evolution of mix design concepts

I. During 1900's, the technique, of using bitumen in pavements, was first used on rural roads in order to prevent rapid removal of the fine particles such as dust, from Water Bound Macadam, which was caused due to fast growth of automobiles [Roberts et al. 2002]. At initial stages, heavy oils were used as dust palliative. An eye estimation process which is called pat test, was used to estimate the required quantities of the heavy oil, in the mix.

II. The 1st formal method of mix design was Habbard field method, which was actually developed on sand-bitumen mixture. Mixtures with larger sized aggregate particles could not be handled in this method. This was one limitation of this procedure.

III. Fransis Hveem, 1942; who was a project engineer of California Department of Highways, has developed the Hveem stabilometer in 1927. He did not have any previous experience on judging, the required mix from its colour, hence he decided to measure various mixture parameters to find the optimum quantity of bitumen [Vallerga and Lovering 1985]. He had used the surface area calculation concept, (which was already in use, at that time for the cement concrete mix design), to estimate the quantity of bitumen actually required.

IV. Bruce Marshall developed the Marshall testing machine just before the World War-II. It was adopted in the US Army Corpes of Engineers in 1930's and subsequently modified in 1940's and 50's.

2.2 Polymer modification

I. Bahia and Anderson, 1984; studied the visco-elastic nature of binders and found that, the complex modulus & phase angles of the binders, need to be measured, at temperatures and loading rates which different resemble climatic and loading conditions.

II. Shukla and Jain (1984) described that the effect of wax in bitumen can be reduced by adding EVA (Ethyl Vinyl Acetate), aromatic resin and SBS in the waxy bitumen. The addition of 4% EVA or 6% SBS or 8% resin in waxy bitumen effectively reduces the Susceptibility to high temperatures, bleeding at high temperature and brittleness at low temperature of the mixes.

III. The findings of the studies conducted by the Shell Research and Technology Centre in Amsterdam indicated that the rutting rate is greatly reduced as a result of SBS modification of the binder. Button and Little (1998) on the basis of stress controlled fatigue testing at 20 and 0^0C, reported that SBS polymer exhibited superior fatigue properties as compared to straight AC-5 bitumen.

IV. Shuler et al. (1987) found that the tensile strength of SBS modified binder increased significantly as compared to unmodified asphalt mix at minus 21, 25 and 41^0C.

V. Collins et al. (1991) and Baker (1998) observed that SBS modified asphalt mixes have longer lives than unmodified asphalt mixes. The addition of SBS polymer to unmodified bitumen also increases its resistance to low temperature cracking.

VI. Denning and Carswell (1981) reported that asphalt concrete using polyethylene modified binders were more resistant to permanent deformation at elevated temperature.

VII. Palit et al. (2002) found improvement in stripping characteristics of the crumb rubber modified mix as compared to unmodified asphalt mix.

VIII. Sibal et al. (2000) evaluated flexural fatigue life of asphalt concrete modified by 3% crumb rubber as part of aggregates.

IX. Goodrich (1998) reported that fatigue life and creep properties of the polymer modified mixes increased significantly as compared to unmodified asphalt mixes.

X. The Indian Roads Congress Specifications Special Publication: 53 (2002) indicate that the time period of next renewal may be extended by 50% in case of surfacing with modified bitumen as compared to unmodified bitumen.

2.3 Recent applications

I. A 25 km plastic modified bituminous concrete road was laid in Bangalore. This plastic road showed superior smoothness, uniform behaviour and less rutting as compared to a plastics-free road which was laid at same time, which began developing “crocodile cracks” very soon after. The process has also been approved, in 2003 by the CRRI (Central Road Research Institute Delhi).

II. Justo et al (2002), at the Centre for Transportation Engineering, of Bangalore University used processed plastic bags as an additive in asphalt concrete mixes. The properties of this modified bitumen were compared to that of ordinary bitumen. It was noted that penetration and ductility values, of modified bitumen was decreasing with the increase in proportion of the plastic additive, up to 12 % by weight.

III. Mohammad T. Awwad et al (2007), polyethylene as one sort of polymers is used to investigate the potential prospects to enhance asphalt mixture properties. The objectives also include determining the best type of polyethylene to be used and its proportion. Two types of polyethylene were added to coat the aggregate High Density Polyethylene (HDPE) and Low Density Polyethylene (LDPE). The results indicated that grinded HDPE polyethylene modifier provides better engineering properties. The recommended proportion of the modifier is 12% by the weight of bitumen content. It is found to increase the stability, reduce the density and slightly increase the air voids and the voids of mineral aggregate.

IV. Shankar et al (2009), crumb rubber modified bitumen (CRMB 55) was blended at specified temperatures. Marshall's mix design was carried out by changing the modified bitumen content at constant optimum rubber content and subsequent tests have been performed to determine the different mix design characteristics and for conventional bitumen (60/70) also. This has resulted in much improved characteristics when compared with straight run bitumen and that too at reduced optimum modified binder content (5.67%).

CHAPTER 3

RAW MATERIALS

RAW MATERIALS

3.1 Basic materials

The materials used are as follows.

i. Aggregates
ii. Bituminous Binder
iii. Mineral Filler
iv. Polythene

3.1.1 Aggregate

Aggregate constitutes the granular part in bituminous concrete mixtures which contributes up to 90-95 % of the mixture weight and contributes to most of the load bearing & strength characteristics of the mixture. Hence, the quality and physical properties of the aggregates should be controlled to ensure a good pavement. The properties that aggregates should have to be used in pavement are shown below

1) Aggregates should have minimal plasticity. The presence of clay fines in bituminous mix can result in problems like swelling and adhesion of bitumen to the rock which may cause stripping problems. Clay lumps and friable particles should be limited to utmost 1%.
2) Durability or resistance to weathering should be measured by sulphate soundness testing.
3) The ratio of dust to asphalt cement, by mass should be a maximum of 1.2 & a minimum of 0.6.
4) It is recommended AASHTO T-209 to be used for determining the maximum specific gravity of bituminous concrete mixes.

5) Aggregates are of 2 types. i.e.

a) Coarse Aggregate (CA)

b) Fine Aggregate (FA)

Coarse Aggregate (CA)

The aggregates retained on 4.75 mm ARE Sieve is called as coarse aggregates. Coarse aggregate should be screened crushed rock, angular in shape, free from dust particles, clay, vegetations and organic matters. They should have following properties

1) The Los Angeles Abrasion value shall not be more than 25 % (ASTM C131).
2) The weighted average weight loss in magnesium sulphate soundness test shall not be more than 18% (AASTHO T 104).
3) Flakiness index shall not be more than 25% (MS 30).
4) The water absorption should not be more than 2% (MS30)
5) The polished stone value should not be less than 40%.

Fine Aggregate (FA)

Fine aggregate should be clean screened quarry dusts. It should be free from clay, loam, vegetation or organic matter. FA should have the following properties

1) The angularity should not be less than 45% (ASTM C 1252).
2) The methylene blue shall not be more than 10 mg/g (Ohio Department of Transportation Standard Test Method).
3) The weighted average weight loss in magnesium sulphate soundness test shall not be more than 20% (AASTHO T 104).
4) The absorption of water, should not be more than 2% (MS30)

3.1.2 Bitumen

Asphalt binder 60/70 and 80/100 are used in this research. The bitumen used should have the following properties.

a) Grade of bitumen used in the pavements should be selected on the basis of climatic conditions and their performance in past.

b) It is recommended that the bitumen should be accepted on certification by the supplier (along with the testing results) and the State project, verification samples. The procedures for acceptance should provide information, on the physical properties of the bitumen in timely manner.

c) The physical properties of bitumen used which are very important for pavements are shown below. Each State should obtain this information (by central laboratory or supplier tests) and should have specification requirements for each property except specific gravity.

(a) Penetration at 77° F

(b) Viscosity at 140° F

(c) Viscosity at 275° F

(d) Ductility/Temperature

(e) Specific Gravity

(f) Solubility

(g)Thin Film Oven (TFO)/Rolling TFO; Loss on Heating

(h) Residue Ductility

(i) Residue Viscosity

3.1.3 Mineral Filler

Mineral filler consists of, very fine, inert mineral matter that is added to the hot mix asphalt, to increase the density and enhance strength of the mixture. These fillers should pass through 75µm IS Sieve.

The fillers may be cement or fly ash.

3.2 Materials used

3.2.1 Aggregates

The grades of aggregates and their quantities to be used for preparing Marshall samples were used according to the chart given in the MORTH specification.

TABLE – 3.1: GRADATION OF AGGREGATES

SIEVE SIZE	% RETAINED
26.5 mm	--
19 mm	5
9.5 mm	25
4.75 mm	20
2.36 mm	15
300 μ	23
75 μ	7
Filler (Fly ash)	5

So the aggregates of different grades were sieved through different IS Sieves and they were kept in different containers with proper marking.

Specific Gravity of Coarse aggregate = 2.7

Specific Gravity of Fine aggregate = 2.6

3.2.2 Bitumen

The bitumen used in preparing Marshall samples was of 80/100 penetration grade.

Specific Gravity bitumen = 1.02

3.2.3 Filler

The filler material used was fly ash.

Specific gravity of fly ash = 2.2

3.2.4 Polythene

The polythene used in OMFED milk packets was used as raw material for preparation of the samples. These polythene packets were collected; they were washed and cleaned by putting them in hot water for 3-4 hours. They were then dried.

Specific Gravity of polythene = 0.905

Shredding:

The dried polythene packets were cut into tiny pieces of size 2 mm maximum. This is because when the polythene is to be added with bitumen and aggregate it is to be ensured that the mixing will be proper. The smaller the size of the polythene, the more is the chance of good mixing.

Figure – 3.1: OMFED Polythene used

Figure – 3.2: SHREDDED POLYTHENE

CHAPTER 4

EXPERIMENTAL WORK

EXPERIMENTAL WORK

4.1 General

It involves mainly 2 processes. i.e.

a) Preparation of samples

b) Void analysis

c) Testing

Prior to these experiments, the specific gravity of polythene used was calculated as per the guidelines provided in ASTM D792-08.

4.1.1 Determination of specific gravity of polythene

The procedure adopted is given below

1) The weight of the polythene in air was measured by a balance. Let it be denoted by “a”.
2) An immersion vessel full of water was kept below the balance.
3) A piece of iron wire was attached to the balance such that it is suspended about 25 mm above the vessel support.
4) The polythene was then tied with a sink by the iron wire and allowed to submerge in the vessel and the weight was measured. Let it be denoted as “b”.
5) Then polythene was removed and the weight of the wire and the sink was measured by submerging them inside water. Let it be denoted as “w”.

The specific gravity is given by

$$\boxed{\mathbf{s = a / (a + w - b)}}$$

where:

a = apparent mass of specimen, without wire or sinker, in air

b = apparent mass of specimen and of sinker completely immersed and of the wire partially immersed in liquid

w = apparent mass of totally immersed sinker and of partially immersed wire.

From the experiment, it was found that

a = 19 gm

b = 24 gm

w = 26 gm

=> s = 19 / (19+26-24) = 19/21 =0.90476

Take s = 0.905.

4.2 Sample Preparation

4.2.1 Marshall Sampling Mould

The specifications of the Marshall sampling mould and hammer are given in table 4.1

TABLE – 4.1: Dimensions of Marshall Sampling mould & hammer

APPARATUS	VALUE	WORKING TOLERANCE
	MOULD	
Average internal diameter, mm	101.2	± 0.5
	HAMMER	
Mass, kg	4.535	± 0.02
Drop Height, mm	457	± 1.0
Foot diameter, mm	98.5	± 0.5

Figure – 4.1: MARSHALL SAMPLING MOULD

Figure – 4.2: MARSHALL HAMMER

4.2.2 Mixing Procedure

The mixing of ingredients was done as per the following procedure (STP 204-8).

1) Required quantities of coarse aggregate, fine aggregate & mineral fillers were taken in an iron pan.
2) This was kept in an oven at temperature 160^0C for 2 hours. This is because the aggregate and bitumen are to be mixed in heated state so preheating is required.
3) The bitumen was also heated up to its melting point prior to the mixing.
4) The required amount of shredded polythene was weighed and kept in a separate container.
5) The aggregates in the pan were heated on a controlled gas stove for a few minutes maintaining the above temperature.
6) The polythene was added to the aggregate and was mixed for 2 minutes.
7) Now bitumen (60 gm), i.e. 5% was added to this mix and the whole mix was stirred uniformly and homogenously. This was continued for 15-20 minutes till they were properly mixed which was evident from the uniform colour throughout the mix.
8) Then the mix was transferred to a casting mould.
9) This mix was then compacted by the Marshall Hammer. The specification of this hammer, the height of release etc. are given in Table – 4.1.
10) 75 no. Of blows were given per each side of the sample so subtotal of 150 no. of blows was given per sample.
11) Then these samples with moulds were kept separately and marked

Figure – 4.3: MARSHALL SAMPLES

Figure 4.4: CLOSER VIEW OF A MARSHALL SAMPLE

4.2.3 Calculations involved

Total weight of sample = 1200 gm

Optimum Bitumen Content = 5 %

So weight of bitumen = 60 gm

Weight of aggregate + polythene = 1200-60 =1140 gm

The polythene content was varied from 1 to 5 % and for each polythene content, 3 samples were prepared.

The samples were named, the weight of polythene & aggregate for each sample were calculated and shown in Table – 4.2 below.

Table – 4.2: Amounts of raw materials

polythene %	wt of polythene	wt of aggregate
	gm	gm
0	0	1140
0	0	1140
0	0	1140
1	11.4	1128.6
1	11.4	1128.6
1	11.4	1128.6
2	22.8	1117.2
2	22.8	1117.2
2	22.8	1117.2
3	34.2	1105.8
3	34.2	1105.8
3	34.2	1105.8
4	45.6	1094.4
4	45.6	1094.4
4	45.6	1094.4
5	57	1083
5	57	1083
5	57	1083

4.3 Void analysis

For analysis of voids, the samples were weighed in air and also in water so that water replaces the air present in the voids. But by this process some amount of water will be absorbed by the aggregates which give erroneous results. Hence 1st the samples were coated with hot paraffin so that it seals the aggregate-bitumen mix completely and checks the absorption of water into it.

4.3.1 Mix Volumetrics

The volumetric parameters (refer Figure 4.5) are to be checked from the Marshall samples, prior to Marshall test. The following are equations which would be used to determine volumetric parameters such as VMA, VA, VFB etc. and absorbed bitumen content (P_{ab}). The absorbed bitumen is a important parameter, which is ignored in bituminous mix design in many cases (Chakroborty & Das, 2005)

.

$$VMA = \left(1 - \frac{Gmb}{Gsb} \times Ps\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(1)}$$

$$VA = \left(1 - \frac{G_{mb}}{G_{mm}}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2)}$$

$$VFB = \left(\frac{VMA - VA}{VMA}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3)}$$

$$P_{ba} = 100\left[\frac{1}{G_{sb}} - \frac{1}{G_{se}}\right] \times G_b \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(4)}$$

Where,

P_{ba} = Absorbed bitumen content as a percentage by weight of aggregates

G_{mb} = Bulk specific gravity of the mix

G_{mm}= Maximum theoretical specific gravity of the mix

G_{sb} = Bulk specific gravity of aggregates

G_{se} = Effective specific gravity of aggregates

G_b = Specific gravity of bitumen

VMA = Voids in Mineral Aggregates

VA = Air Voids

VFB = Voids filled with Bitumen.

G_{sb} = M_{agg} / volume of (aggregate mass + air void in aggregate + absorbed bitumen) - -(5)

G_{se} = M_{agg} / volume of (aggregate mass + air void in aggregate) - - -(6)

G_a = M_{agg} / volume of aggregate mass - - -(7)

G_{mm} = M_{mix} / volume of mix air voids - - -(8)

G_a = M_{mix} / bulk volume of the mix - - -(9)

$G_{se} = (M_{mix} - M_b) / [(M_{mix} / G_{mm}) – (M_b / G_b)$ - - -(10)

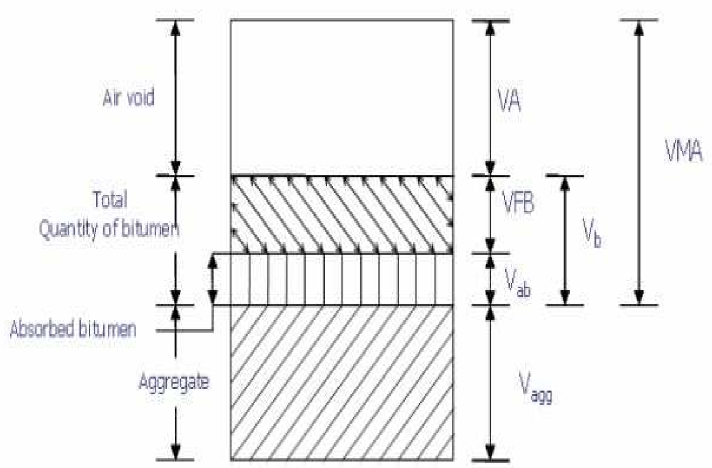

Figure – 4.5: PHASE DIAGRAM FOR MIX VOLUMETRICS

(Chakroborty & Das, Principles of Transportation Engineering)

To calculate value of G_{mb} we need to calculate the bulk volume of the sample for which 3 readings are needed. i.e.

- Weight of sample in air
- Weight of paraffin coated sample in air
- Weight of paraffin coated sample in water

All the parameters are shown in Table – 4.3, 4.4 & 4.5

Table – 4.3: Calculation of G_{sb}

polythene %	% of CA	% of FA	% of filler	% of pol	G_{sb}	G_{mm}
0	47.5	42.75	4.75	0	2.624745	2.43333
0	47.5	42.75	4.75	0	2.624745	2.43333
0	47.5	42.75	4.75	0	2.624745	2.43333
1	47.025	42.3225	4.7025	0.95	2.61319	2.393276
1	47.025	42.3225	4.7025	0.95	2.61319	2.393276
1	47.025	42.3225	4.7025	0.95	2.61319	2.393276
2	46.55	41.895	4.655	1.9	2.601737	2.354519
2	46.55	41.895	4.655	1.9	2.601737	2.354519
2	46.55	41.895	4.655	1.9	2.601737	2.354519
3	46.075	41.4675	4.6075	2.85	2.590384	2.316998
3	46.075	41.4675	4.6075	2.85	2.590384	2.316998
3	46.075	41.4675	4.6075	2.85	2.590384	2.316998
4	45.6	41.04	4.56	3.8	2.579129	2.280653
4	45.6	41.04	4.56	3.8	2.579129	2.280653
4	45.6	41.04	4.56	3.8	2.579129	2.280653
5	45.125	40.6125	4.5125	4.75	2.567971	2.245431
5	45.125	40.6125	4.5125	4.75	2.567971	2.245431
5	45.125	40.6125	4.5125	4.75	2.567971	2.245431

Table – 4.4: Calculation of G_{mb} & bulk volume

Sample no.	polythene %	wt of sample in air(W)	Wt of paraffin coated sample in air(W_1)	Wt of paraffin coated sample in water(W_2)	Bulk volume	G_{mb}
		gm	gm	gm	cc	
1'	0	1196	1215	675	518.88889	2.304925
2'	0	1196	1214	678	516	2.317829
3'	0	1197	1215	679	516	2.319767
1	1	1202	1220	676	524	2.293893
2	1	1194	1213	674	517.88889	2.305514
3	1	1193	1212	674	516.88889	2.30804
4	2	1194	1224	666	524.66667	2.275731
5	2	1197	1224	667	527	2.271347
6	2	1192	1223	671	517.55556	2.303134
7	3	1206	1224	670	534	2.258427
8	3	1196	1222	661	532.11111	2.247651
9	3	1195	1225	660	531.66667	2.247649
10	4	1203	1221	659	542	2.219557
11	4	1205	1223	662	541	2.227357
12	4	1212	1230	661	549	2.20765
13	5	1209	1228	655	551.88889	2.190658
14	5	1210	1229	657	550.88889	2.19645
15	5	1208	1230	652	553.55556	2.182256

Table – 4.5: Calculation of VMA, VA, VFB

Sample no.	polythene %	VMA	VA	VFB
1'	0	16.57556291	5.276911	68.16452
2'	0	16.10850103	4.746592	70.53362
3'	0	16.03835764	4.666949	70.90133
1	1	15.39714962	4.152575	73.03023
2	1	14.96855727	3.667019	75.50186
3	1	14.87540443	3.561485	76.05789
4	2	14.50180437	3.346262	76.9252
5	2	14.6664858	3.532431	75.91495
6	2	13.47225683	2.182382	83.80091
7	3	13.59858552	2.527865	81.41082
8	3	14.01085046	2.992954	78.63831
9	3	14.01092559	2.993039	78.63782
10	4	13.55906408	2.678882	80.24287
11	4	13.25530957	2.336894	82.37013
12	4	14.02278068	3.200966	77.1731
13	5	13.17783405	2.439313	81.48927
14	5	12.94828672	2.181374	83.15318
15	5	13.5108386	2.813505	79.17594

4.4 Marshall testing

The Marshall test was done as procedure outlined in ASTM D6927 – 06.

Marshall Stability Value :

It is defined as the maximum load at which the specimen fails under the application of the vertical load. It is the maximum load supported by the test specimen at a loading rate of 50.8 mm/minute (2 inches/minute). Generally, the load was increased until it reached the maximum & then when the load just began to reduce, the loading was stopped and the maximum load was recorded by the proving ring.

Marshall Flow Value :

It is defined as the deformation undergone by the specimen at the maximum load where the failure occurs. During the loading, an attached dial gauge measures the specimen's plastic flow as a result of the loading. The flow value was recorded in 0.25 mm (0.01 inch) increments at the same time when the maximum load was recorded.

Two readings were taken from the dial gauge i.e. initial reading (I) & final reading (F)

The Marshall Flow Value (f) is given by

$$\boxed{f = F - I}$$

The Marshall Stability Values are shown in Table – 4.6

The Marshall Flow Values are shown in Table – 4.7

Table – 4.6: MARSHALL STABILITY VALUE (S)

Sample no.	polythene %	No. of divisions (N)	Marshall Stability Value (S)
			kN
1'	0	460	13.66
2'	0	500	14.85
3'	0	490	14.56
1	1	490	14.56
2	1	470	13.96
3	1	480	14.26
4	2	490	14.56
5	2	480	14.26
6	2	500	14.85
7	3	520	15.44
8	3	530	15.74
9	3	520	15.44
10	4	570	16.93
11	4	600	17.82
12	4	620	18.41
13	5	540	16.04
14	5	520	15.44
15	5	550	16.34

Table – 4.7: MARSHALL FLOW VALUE

Sample no.	polythene %	Initial Reading (I)	Final Reading (F)	Marshall Flow Value (F)
				mm
1'	0	3.1	7.3	4.2
2'	0	3.3	7.4	4.1
3'	0	3.3	7.4	4.1
1	1	3.5	7.0	3.5
2	1	3.2	7.9	3.7
3	1	4.1	7.3	3.2
4	2	3.9	7.0	3.1
5	2	3.7	6.7	3
6	2	3.2	6.3	3.1
7	3	3.9	7.1	3.2
8	3	3.0	5.8	2.8
9	3	3.1	6.0	2.9
10	4	2.8	5.3	2.5
11	4	2.6	5.5	3.3
12	4	3.3	6.1	2.8
13	5	2.9	5.5	2.6
14	5	3.2	5.9	2.7
15	5	3.3	6.2	2.9

CHAPTER 5

ANALYSIS OF RESULTS

ANALYSIS OF RESULTS

5.1 Plotting Curves

5 curves were plotted. i.e.

i. Marshall Stability Value vs. Polythene Content

ii. Marshall Flow Value vs. Polythene Content

iii. VMA vs. Polythene Content

iv. VA vs. Polythene Content

v. VFB vs. Polythene Content

vi. Bulk unit weight vs. Polythene Content

For each % of polythene, 3 samples have been tested. So the average value of the 3 were taken. The mean values are shown in Table – 5.1

Table – 5.1: Data for plotting curves

Polythene Content (%)	Unit weight (G_{mb})	Mean VMA (%)	Mean VA (%)	Mean VFB (%)	Mean S (kN)	Mean F (mm)
0	2.668241	16.24080719	4.896817	69.86649	14.35667	2.314174
1	2.628602	15.08037044	3.793693	74.86333	14.26	2.302482
2	2.584494	14.21351566	3.020358	78.88036	14.55667	2.283404
3	2.56012	13.87345386	2.837953	79.56232	15.54	2.251242
4	2.52277	13.61238478	2.738914	79.9287	17.72	2.218188
5	2.457956	13.21231979	2.478064	81.2728	15.94	2.189788

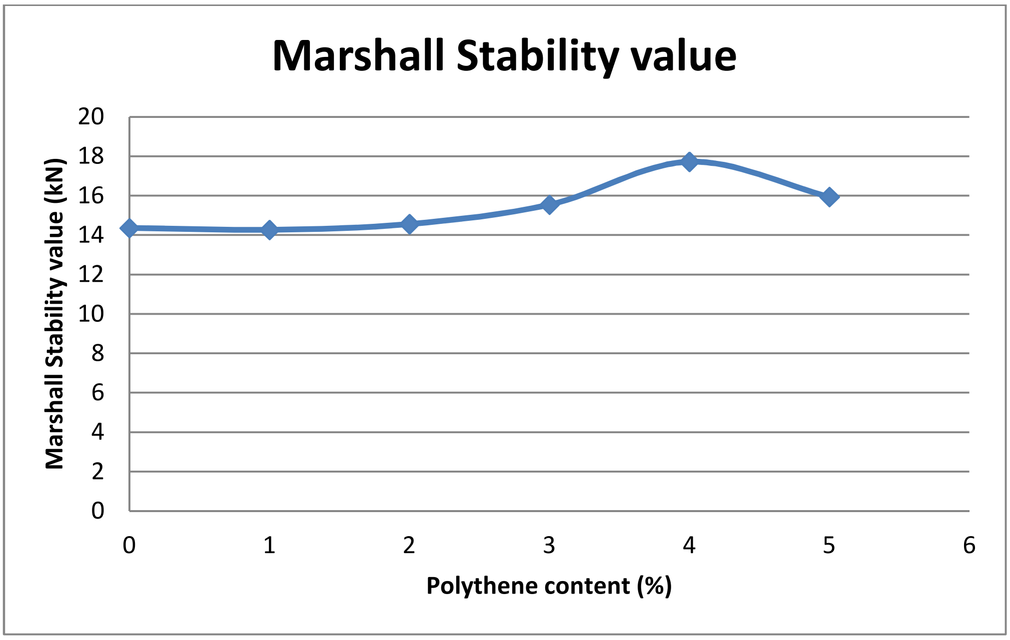

Figure – 5.1: Marshall Stability Value vs. Polythene Content

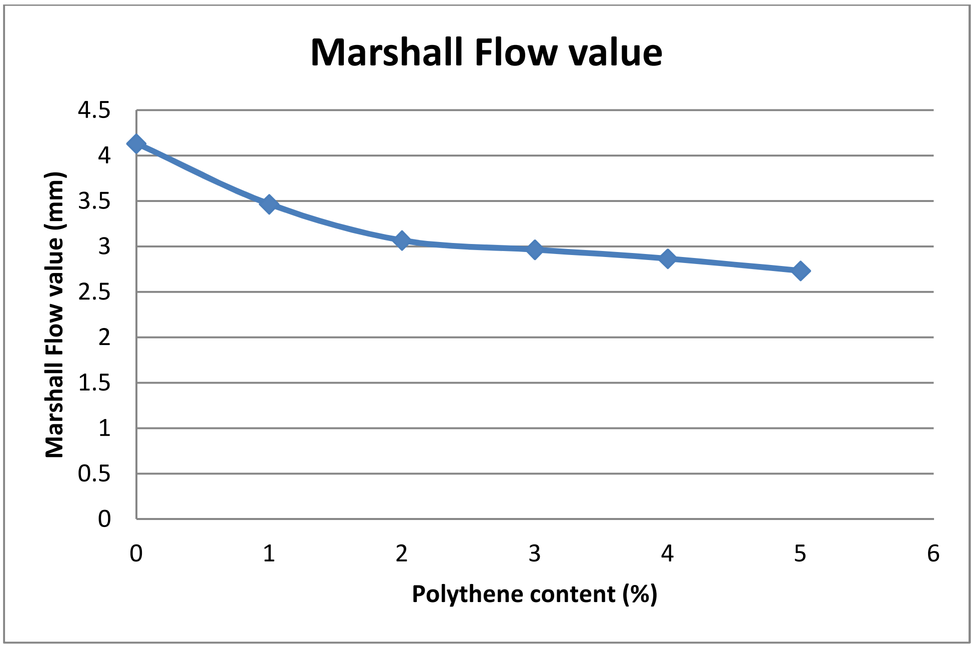

Figure – 5.2: Marshall Flow Value vs. Polythene Content

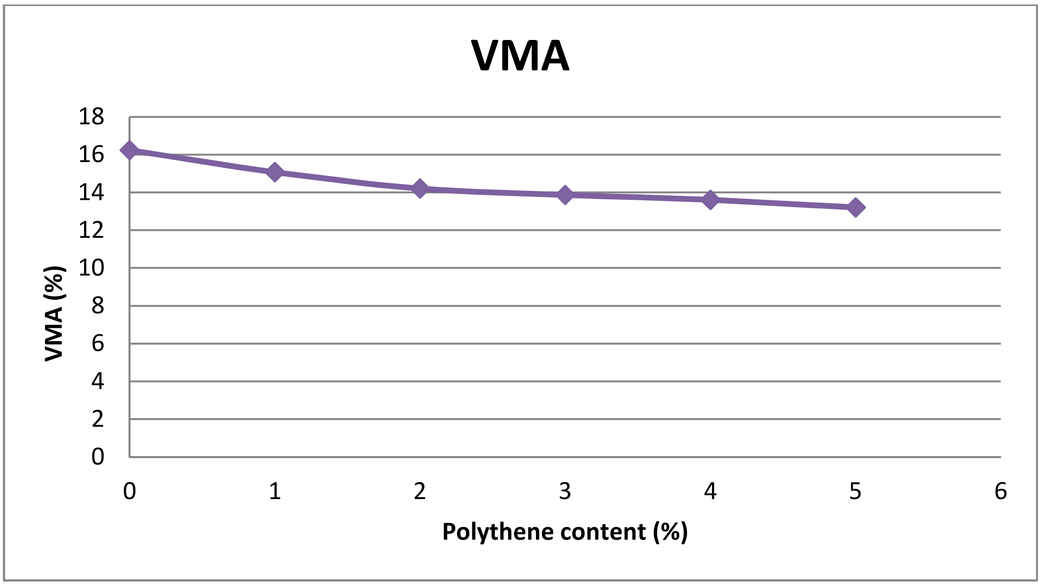

Figure – 5.3: VMA vs. Polythene Content

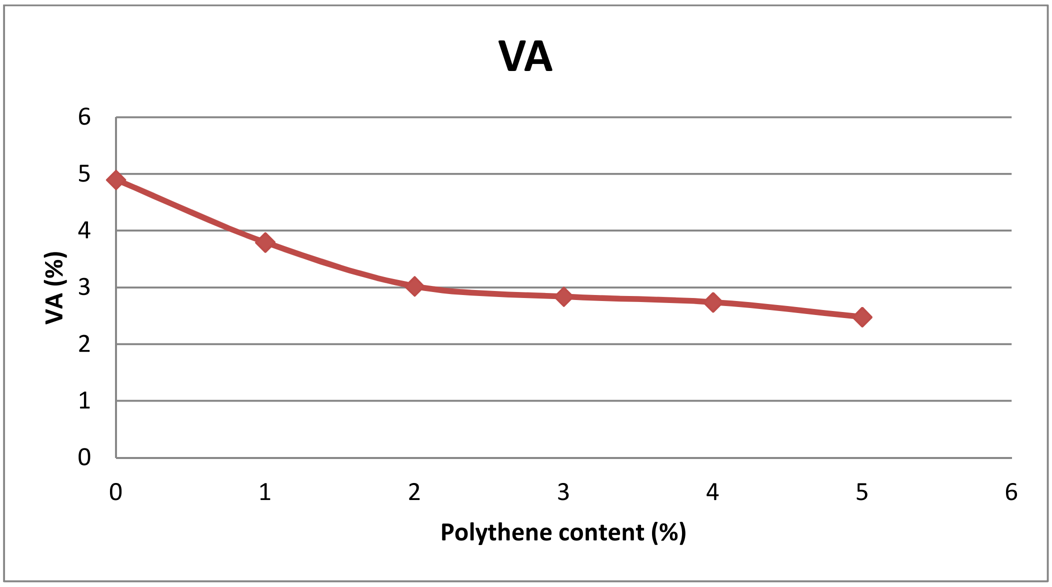

Figure – 5.4: VA vs. Polythene Content

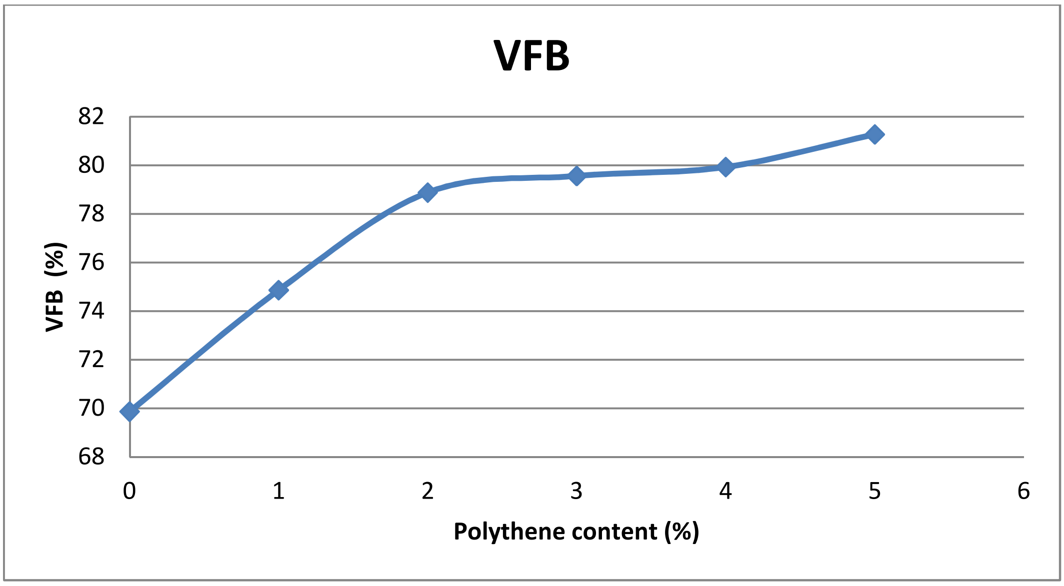

Figure – 5.5: VFB vs. Polythene Content

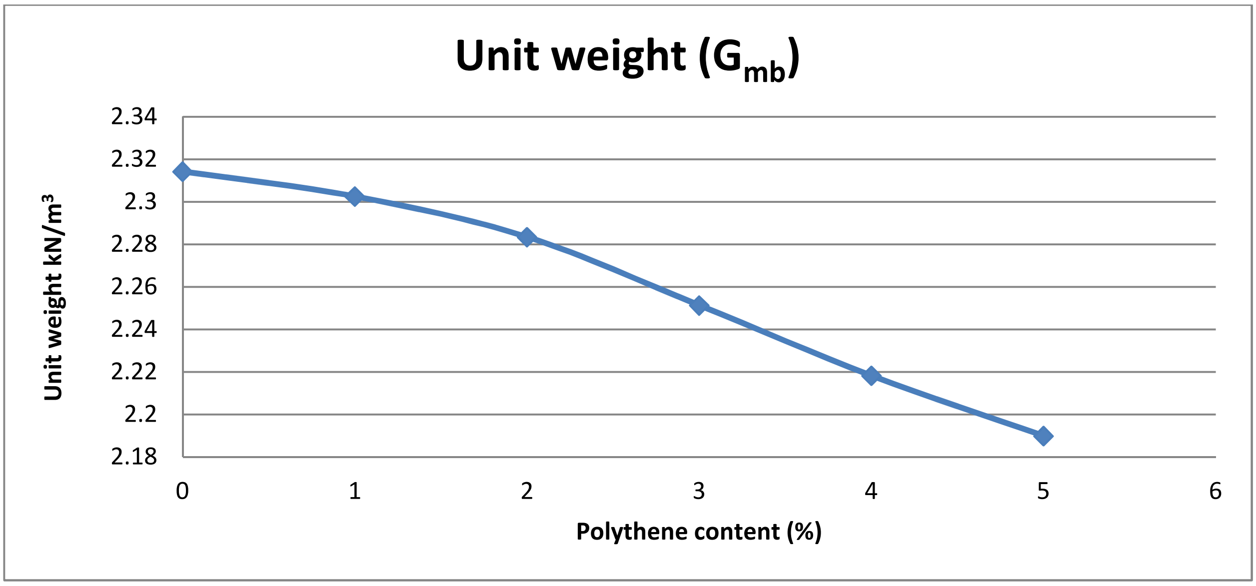

Figure – 5.6: Bulk unit weight vs. Polythene Content

5.2 Analysis

5.2.1 Finding Optimum Polythene Content

The value of polythene content at which the sample has maximum Marshall Stability Value and minimum Marshall Flow Value is called as Optimum Polythene Content.

From the Figure – 5.1 & 5.2 we get the Optimum Polythene Content as 4%.

Also from Figures – 5.3, 5.4 & 5.5 we conclude that upon addition of polythene the voids present in the mix decreases.

CHAPTER 6

CONCLUSIONS

CONCLUSIONS

6.1 General

From the study of the behaviour of polythene modified BC it was found that the modified mix possesses improved Marshall Characteristics as mentioned below.

It is observed that Marshall stability value increases with polyethylene content upto 4% and thereafter decreases. we observe that the marshall flow value decreases upon addition of polythene i.e the resistance to deformations under heavy wheel loads increases. Also the values of the parameters like VMA, VA, VFB are within the required specifications.

Considering these factors we can assure that we can obtain a more stable and durable mix for the pavements by polymer modifications. This small investigation not only utilizes beneficially, the waste non-degradable plastics but also provides us an improved pavement with better strength and longer life period.

Polymer modified pavements would be a boon for India's hot and extremely humid climate, where temperatures frequently rises past 50°C and torrential rains create havoc, leaving most of the roads with heavy distresses. This adversely affects the life of the pavements. The polymer modified bitumen show improved properties for pavement constructions. This also can reduce the amount of plastics waste which otherwise are considered to be a threat to the hygiene of the environment.

In this modification process plastics-waste is coated over aggregate. This increases the surface area of contact at the interface and ensures better bonding between aggregate and bitumen. The polymer coating also reduces the void spaces present in the mix. This prevents the moisture absorption and oxidation of bitumen by entrapped air. The road can withstand heavy traffic and show better service life. This study will have a positive impact on the environment as it will reduce the volume of plastic waste to be disposed off by incineration and land filling. It will not only add value to plastic waste but will develop a technology, which is eco-friendly.

However, it is recommended that more research regarding the topic should be done and more trial sections should be laid and their performance should be studied.

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